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THE FLAMMABILITY OF CERTAIN GUARDRAIL IV SYSTEM TRAILER COMPONENTS

DOMENIC P. MACAIONE
POLYMER RESEARCH DIVISION

May 1982

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ABSTRACT

A series of materials used in construction of the interior of some Guardrail IV system trailers has been investigated by thermogravimetric, oxygen index-temperature index, smoke density, and flash ignition analyses. As a result of this investigation some insight into the flammability characteristics of these materials has been obtained. Recommendations are made regarding characteristics to be favored in materials selection.

CONTENTS

INTRODUCTION

At the request of TSARCOM,* St. Louis, Missouri, samples of certain materials employed in the interior construction of trailer-type enclosures for the Guardrail IV system by Electromagnetic Systems Laboratories (ESL), Sunnyvale, California, were submitted to this laboratory for testing under a continuing research program on the flammability of organic materials.

The test samples, as received, consisted of the following:

a) Foam Insulation - two pieces of rigid foam insulation, 8"x8", composed of Type 115 oversprayed with Type 250. This configuration was employed to insulate the space between the exterior shell and the interior wall surface. The two types of foam were separated and evaluated individually. When divided, the thickness of each type of foam varied from nil to approximately one inch.

b) Foam Insulation - two pieces of flexible, grey, foam insulation, 2"x12"x3/4", employed to insulate around air conditioning units.

c) Wall Covering - Type 1, one piece, rigid, fiber reinforced, tan color approximately 9"x9"x1/8". This material was employed as the interior wall surface over the combined 115/250 foam insulation.

d) Mounting Channel - one piece, white, flexible, approximately 2"x14". This item was employed to hold the wall covering in place. Thickness of the preformed sample varied from 1/16" to 1/32".

e) Floor Tile - one piece, tan, approximately 9"x9"x1/8".

f) Ceiling Tile - one piece, white outer surface, approximately 7"x7"x1/2".

These six samples were brought to the laboratory from an existing field unit. Subsequently, four additional samples of materials proposed for use in trailer-type enclosures were submitted for evaluation.

g) Wall Covering - Type 2, two pieces, rigid, white, fiber reinforced, approximately 12"x12"x1/8".

h) Glass Fiber Insulation - two pieces, 2-1/2" thick with one aluminum foil face, approximately 12"x12".

i) Silicone Caulk - one tube, 10 oz., General Electric #2567-512, metallic.

j) Silicone Caulk - one tube, 3 oz., General Electric #133, black.

These materials were subjected to laboratory-scale evaluation to determine their flammability characteristics.

*TSARCOM, Troop Support and Aviation Materiel Readiness Command.

EXPERIMENTAL

Thermogravimetric Analysis (TGA)

A thermogravimetric analysis system consisting of a DuPont 990 Thermal Analyzer and 951 TGA module was employed to determine weight loss as a function of temperature in flowing air, at a preset flow rate of 50 cc/min, for each material. The resultant data indicates the thermal stability of the material. In general, materials which are thermally stable are less flammable than those which are thermally labile since the concentration of low molecular weight fragments is reduced for a given temperature up to the point where major decomposition occurs.

Oxygen Index-Temperature Index Analysis (OI-TI)

As a measure of the susceptibility to ignition the limiting oxygen index value was determined with a Stanton-Redcroft FTA apparatus for each material, and when considered necessary the material was evaluated at elevated temperature with a Stanton-Redcroft HFTA apparatus to determine the temperature index profile. Essentially, this consists of a determination of the minimum oxygen concentration of a flowing oxygen nitrogen mixture which is required to support equilibrium burning of a vertically oriented 1/4"x1/2"x3" sample of the material under test at gas stream temperatures of ambient to 300°C.

Smoke Density Measurements

The materials were tested in an NBS smoke density chamber with a volume of 18 cubic feet, fitted with a vertically oriented photometer, to determine the smoke density value for each sample material. The samples were tested only in the smoldering mode wherein material under test is subjected to the thermal energy of an electric furnace such that the sample surface receives 2.5 watt/cm^2. In this condition the surface temperature is 350°C. The smoke density value is determined by the decrease in light transmission as measured by the photometer. Values of maximum optical density (D_m) and/or specific optical density (D_s) are quoted, as appropriate. Larger values indicate more smoke is produced by the sample.

Flash Ignition Temperature

The materials were tested for flash ignition temperature by placement of a pilot flame above the exit port of an autoignition apparatus consisting of a 3-inch-diameter furnace tube which is electrically heated and through which air is passed at a preset flow rate. The sample is held in a ceramic cup within the furnace and the temperature of the heating coils, air stream, sample cup, and sample are monitored with thermocouples. The flash ignition temperature is that sample temperature at which sufficient combustible vapor is mixed with air and passes upward to the pilot flame to cause a flashback and combustion of the sample.

RESULTS

Thermogravimetric Analysis (TGA)

The results of the thermogravimetric analysis experiments are shown in Table 1. and for illustrative purposes graphic plots of weight loss as a function of temperature are shown in Figure 1.

Table 1. TGA OF GUARDRAIL IV TRAILER COMPONENTS

	MATERIAL	INITIAL WT LOSS (°C)	DECOMPOSITION TEMPERATURE (°C)
1.	Foam #115	110	225
2.	Foam #250	55	200
3.	Air condition foam	125	252
4.	Glass wool insulation	-*	-*
5.	Wall covering Type 1	155	330
6.	Wall covering Type 2	200	330
7.	Mounting strip	250	300
8.	Floor tile	180	218
9.	Ceiling tile	50	298
10.	Silicone caulk 2567-512 metallic.	175	450
11.	Silicone caulk 133 black	200	435

*Sample apparently melts at 700°C with no change in weight. Melting was determined by observation after the fact.

Oxygen Index-Temperature Index Analysis (OI-TI)

The results of the oxygen index analysis experiments are shown in Table 2.

Table 2. LIMITING OXYGEN INDEX OF GUARDRAIL IV TRAILER COMPONENTS

	MATERIAL	LOI
1.	Foam #115	20
2.	Foam #250	22
3.	Air condition foam	23
4.	Glass wool insulation	--*
5.	Wall covering Type 1	19-20
6.	Wall covering Type 2	41
7.	Mounting strip	32
8.	Floor tile	39-40
9.	Ceiling tile	46**
10.	Silicone caulk 2567-512 metallic	25
11.	Silicone caulk 133 black	33

* Glass wool melts under ignition source.

** Sample exhibits "glowing combustion" which, once initiated, continues until O_2 concentration is decreasedd to ∿ 22%.

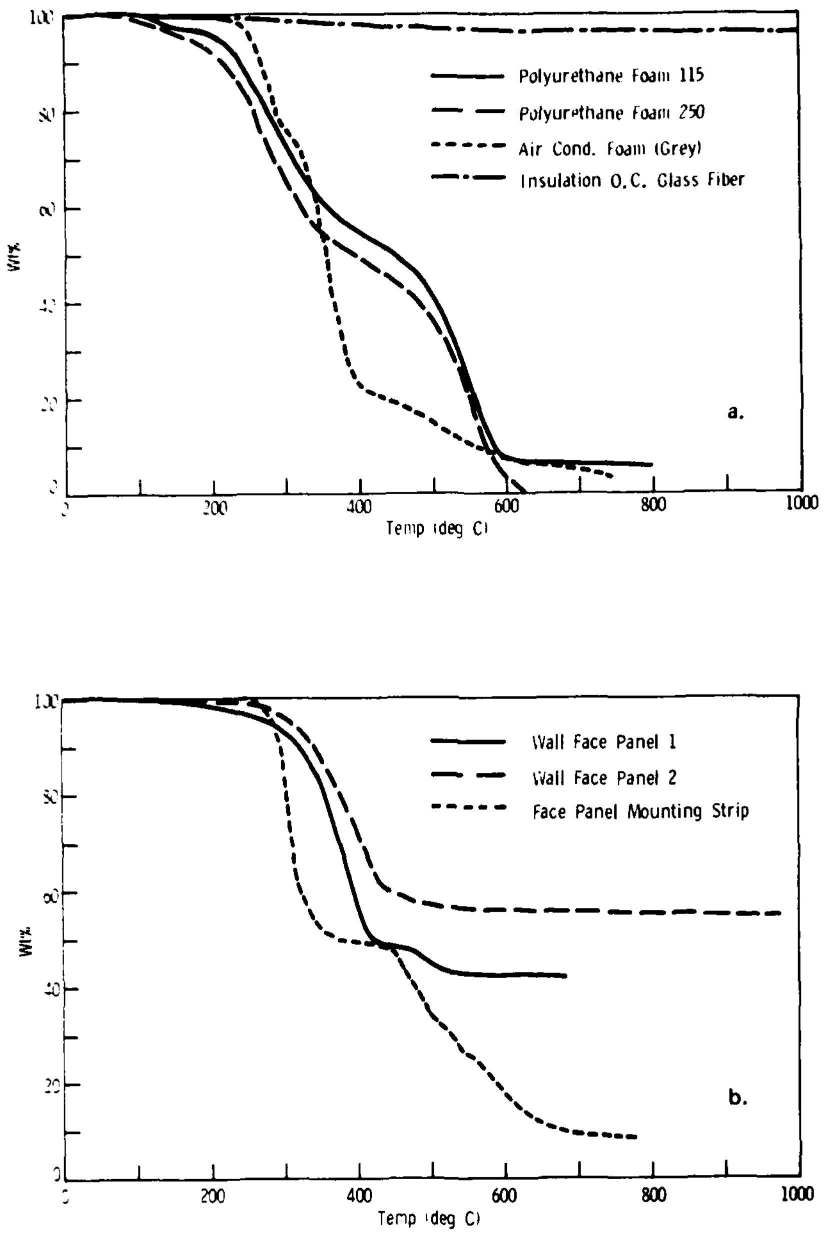
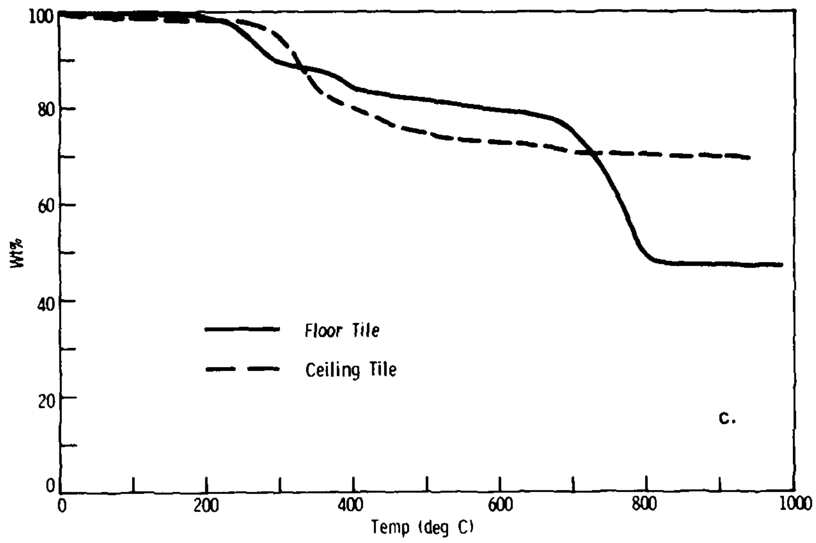


Figure 1. Thermogravimetric analysis profile: weight loss versus temperature.



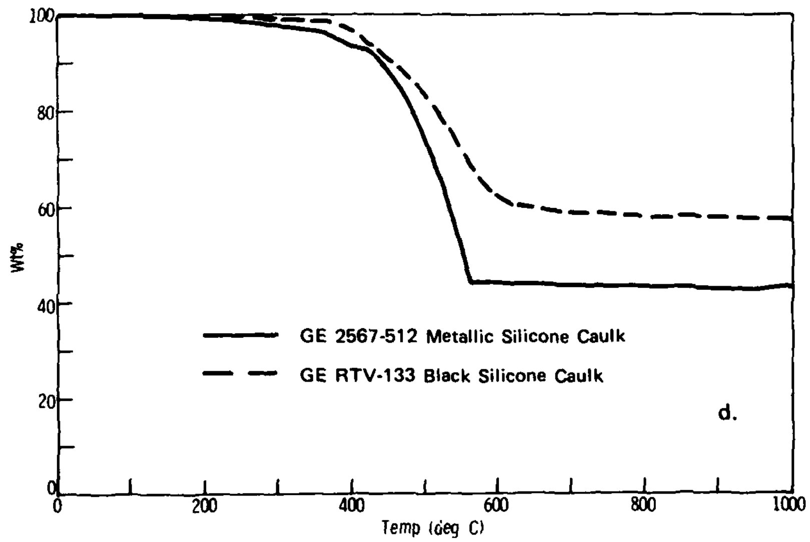


Figure 1. Thermogravimetric analysis profile: weight loss versus temperature (cont'd).

The results of temperature indexing sample number 6 above (wall covering Type 2) to determine the temperature index profile or temperature dependence of oxygen index is shown in Table 3 and Figure 2.

Table 3. TEMPERATURE INDEX PROFILE OF WALL COVERING, TYPE 2

TEMPERATURE(°C)	OXYGEN INDEX
Ambient (25)	41
100	40
200	36
250	18
300	12

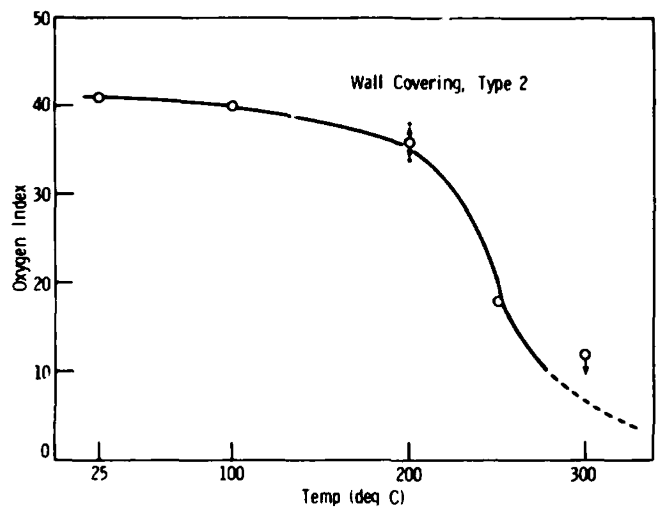


Figure 2. Temperature dependence of oxygen index.

As determined from Figure 2 the temperature at which this material would support combustion in normal atmosphere is approximately 250°C, indicated by the intercept of the temperature index profile with 21% oxygen level.

Foam #250 and silicone caulk #2567-512 were also evaluated by temperature indexing. The results of these experiments are shown in Table 4.

Table 4. TEMPERATURE INDEX PROFILE OF FOAM 250 AND CAULK 2567--512

	OXYGEN INDEX	
TEMPERATURE(°C)	FOAM #250	#2567-512
Ambient (25)	23-24	24-25
100	23-24	16-17
150	19-20	---
200	10	8
300	---	1

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These data are graphically illustrated in Figure 3 and Figure 4. Again, as in the case of wall covering, Type 2, the temperatures at which combustion would be supported in normal atmosphere are indicated by the intercept of the curve and the 21% oxygen level. (Similiar data for RTV-133 could not be determined due to difficulties with sample curing.)

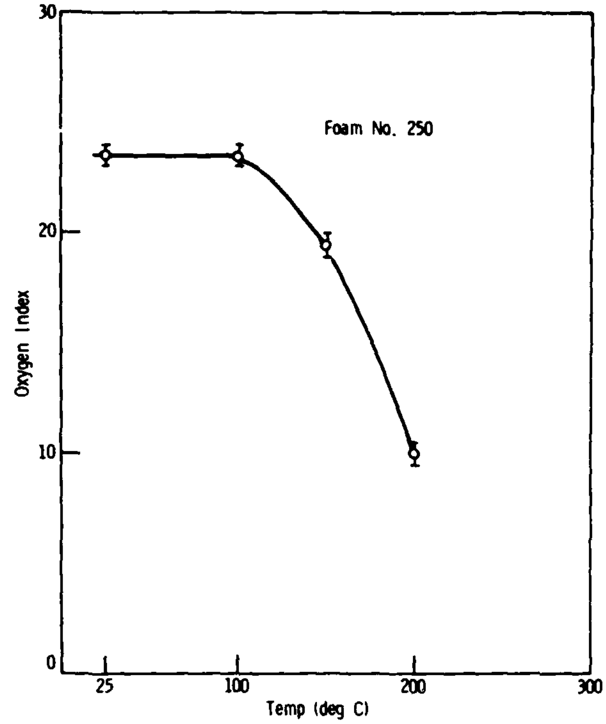

Figure 3. Temperature dependence of oxygen index.

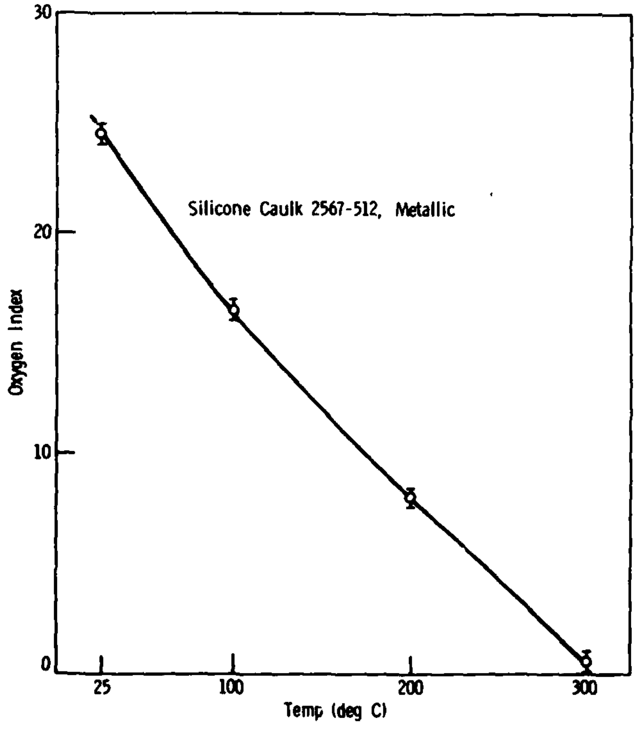

Figure 4. Temperature dependence of oxygen index.

Smoke Density Analysis (SD)

The results of smoke generation measurements perfomed with an NBS smoke density chamber are shown in Table 5.

Table 5. SD ANALYSIS OF GUARDRAIL TRAILER COMPONENTS

MATERIAL	SMOKE DENSITY (D_m coor)	TIME TO $D_s = 16$
1. Foam #115	220	10 seconds
2. Foam #250	104	12 seconds
3. Air condition foam	155	15 seconds
4. Glass wool insulation		
(foil face out)	1	---
4a. (glass out)	3	---
5. Wall covering Type 1	352	3 minutes
6. Wall covering Type 2	179	4 minutes
7. Mounting strip	286	50 seconds
8. Floor tile	270	2 minutes
9. Ceiling tile	50	3 minutes
10. Silicone caulk 2567-512 metallic	341	2 minutes*
11. Silicone caulk 133 black	-	--**

$D_m = 264$ is equal to 1% light transmission

* Sample ignited immediately prior to reaching $D_s = 16$

**Material would not cure in required sample size for analysis

These data are shown in Figures 5-8.

Flash Ignition Analysis

The results of the flash ignition experiments are shown in Table 6.

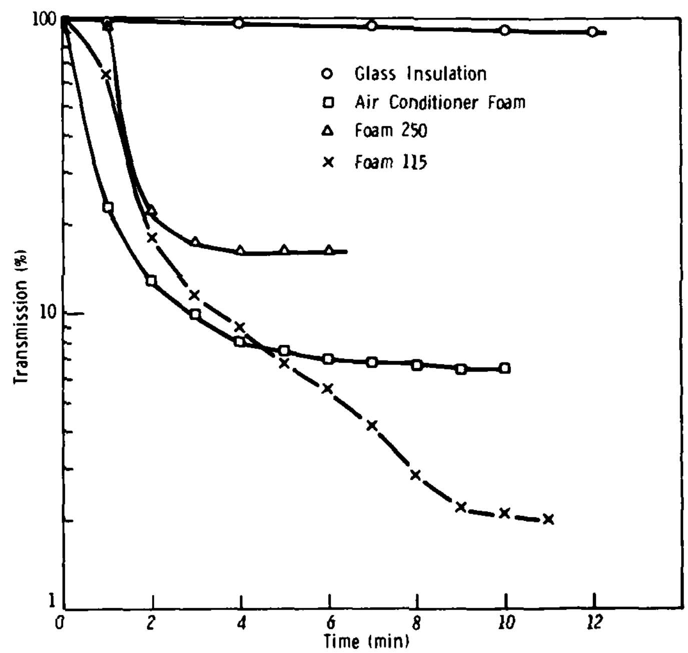

Figure 5. Loss of light transmission versus time.

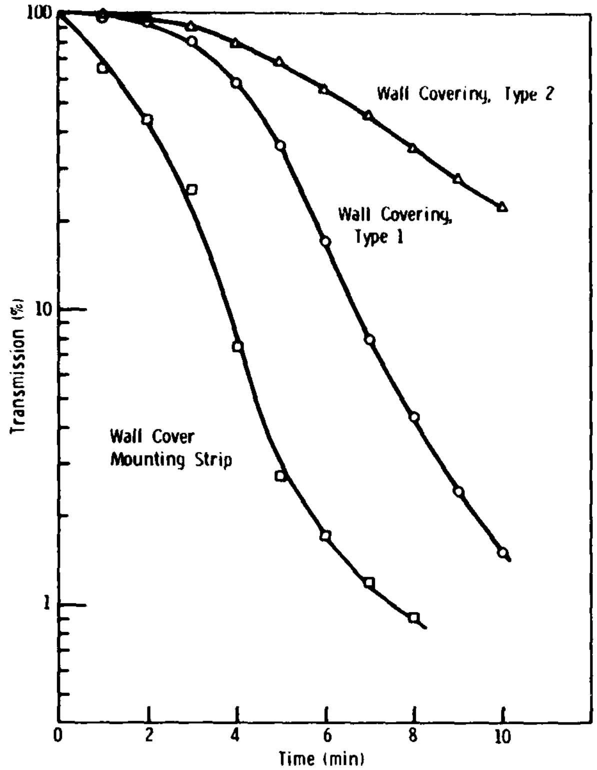

Figure 6. Loss of light transmission versus time.

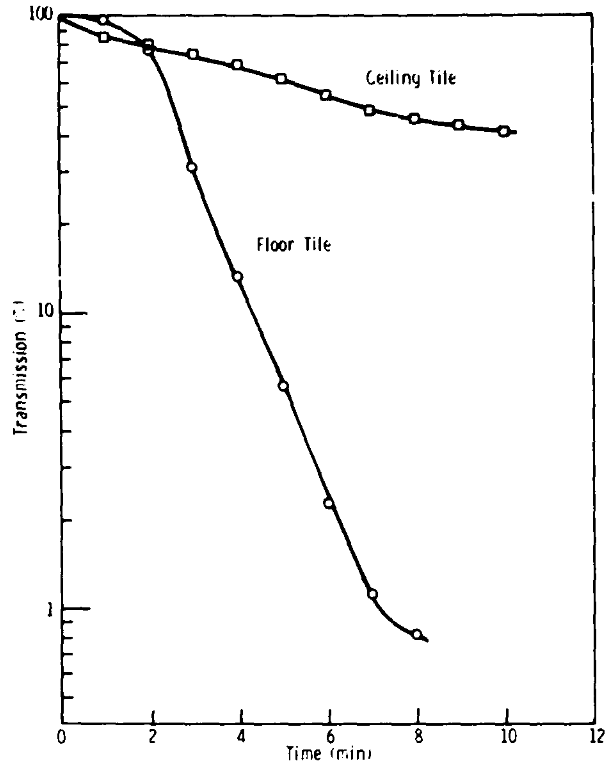

Figure 7. Loss of light transmission versus time.

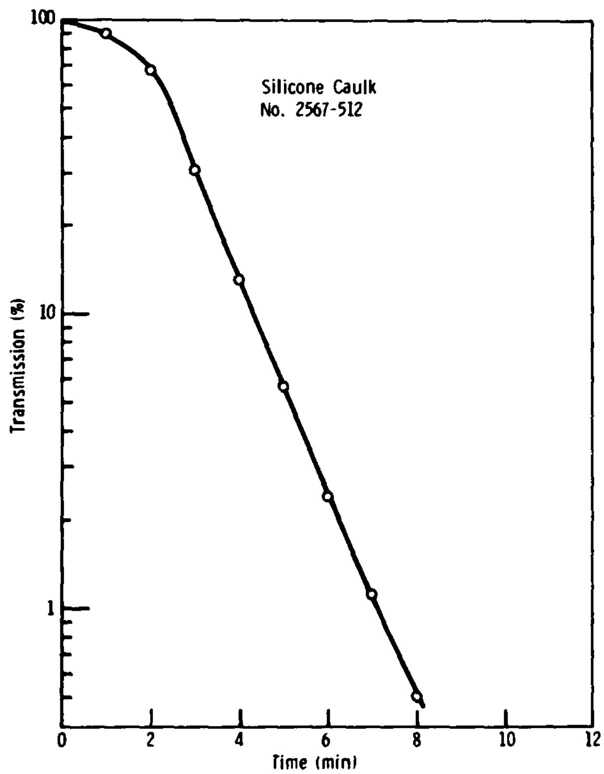

Figure 8. Loss of light transmission versus time.

Table 6. FLASH INGNITION TEMPERATURE OF GUARDRAIL TRAILER COMPONENTS

	MATERIAL	FIT(°C)*	COMMENT
1.	Foam #115	--	Visual loss of glowing particles at 490°.
2.	Foam #250	--	Same effect as 115 foam at 15 ℓ/m ∿500°C.
3.	Air condition foam	360	Melting observed at 270°C.
4.	Glass wool insulation	--	Only slight dis- coloration observed.
5.	Wall covering Type 1	353	
6.	Wall covering Type 2	411	
7.	Mounting strip	408	Sudden and rapid flashover.
8.	Floor tile	--	
9.	Ceiling tile	--	
10.	Silicone caulk 2567-512 metallic	408	
11.	Silicone caulk 133 black	450	

* Measured within sample on thermocouple #4.

Arc Ignition of #115 and #250 Foam Insulation

To test the probability that foam insulation exposed to an electric arc might be ignited by such a source several experiments were conducted in which sections of foam insulation approximately one-half inch thick were subjected to the sustained arc generated by a Tesla Coil while time to ignition was recorded. The #250 foam under these conditions ignited in approximately 100 seconds and subsequently self-extinguished. The #115 foam, however, ignited at times varying from 7-30 seconds and continued to burn until the sample was consumed. This approach is admittedly qualitative, and the time to ignition somewhat variable, depending upon the arc path through the sample. It does, however, illustrate that arcing is a possible source of ignition.

DISCUSSION

The results of thermogravimetric analysis have shown that the major decomposition of the various components tested occurs between 200° and 450°C, except for the glass wool insulation which showed only a slight weight loss over the temperature range of the test. This loss is most likely due to the sizing or other coating used on the glass fibers during processing. The results of the oxygen index-temperature index test indicate that the ease of ignition of the various components tested is quite different, ranging from glass fiber insulation which melted but would not support combustion, to the Type 1 wall covering which could be ignited with the flame of a match in normal atmosphere.

The 115 and 250 foams, and the air conditioner insulating foam, possess nearly equivalent oxygen index values. However, in the case of the 250 foam extensive charring during the experiment makes precise analysis difficult. It has been noted that the 250 foam tends to self-extinguish which may be due to the formation of char or some compositional difference between it and the 115 foam. The 115 foam will continue to burn once it has been ignited which tends to confirm the O.I. value of 20.

The oxygen index analysis of wall covering, Type 1, and wall covering, Type 2, showed marked differences in ignition behavior. The oxygen index of Type 1 was determined as being 19-20 which was confirmed by the fact that it would be set afire with a match flame in normal atmosphere. The oxygen index of Type 2 was recorded as 41. The temperature index profile of this material (Figure 2) indicates that it would not support equilibrium burning in normal atmosphere until a temperature of approximately 250°C had been reached.

Regarding the silicone caulking materials the silicone 2567-512 was observed to undergo "glowing combustion" after ignition while the silicone 133 appeared to self extinguish. Preliminary testing at elevated temperatures also indicated that the 2567-512 material will continue in "glowing combustion" at very low oxygen concentrations. This was later confirmed, as shown in Table 4 and Figure 4, where this material continued to support combustion in less than 10% oxygen when taken above 200°C.

The smoke density experiments were conducted in smoldering mode to evaluate the level and rate of smoke generation of the materials. The values are ultimately based upon obscuration of the light beam of a photometer. Although the data in Table 5 are in terms of density, it is helpful to remember that a D_m value of 264 indicates only 1% of the total light is being transmitted. The data indicates that foam 115, wall covering Type 1, the mounting strip, floor tile, and the silicone caulk 2567-512 represent the greatest smoke hazard in a fire, however, the total quantity of each material present in the area must be taken into account. For example, although the mounting strip and floor tile have similiar D_m values there is more tile present in a trailer than there is wall covering mounting strip. The floor tile would therefore have a greater potential smoke load than the mounting strips. The values of time to reach $D_s = 16$, which is equivalent to 75% light transmission are included for two reasons. First, this value indicates a rate of smoke generation early in the experiment while most of the specimen is intact and second, it represents a light transmission level which some investigators feel is the critical minimum required to discern an escape route which is 10 feet away.

Figures 5-8 show the data obtained in the smoke density experiments plotted in semi-log fashion as percent transmission against time. The data for the insulating materials, and the wall covering materials have been plotted on a common axis to simplify visual comparision of the results for each group of components.

The results of the flash ignition analysis, as shown in Table 6 indicate the five of the materials tested gave no clear indication of flashover under the conditions of the test. This should not be taken to mean that no flash ignition temperature exists, but merely that the proper conditions of heat, oxygen and combustible fragments or gases were not experienced in this test series. Although the flash ignition temperatures may seem quite high, at first glance, it must be remembered that in a fire situation the temperature levels which materials in proximity to the flames will experience can rapidly reach or exceed these values and the ensuing flash ignition can thus add to the total fire load.

CONCLUSIONS

Based upon the experimental observations presented in this report the potential fire hazard of the materials selected for construction becomes evident. There are alternatives available which could reduce the fire hazard from the materials point of view. In general terms materials should be selected that possess limiting oxygen indices of at least 28-30 and do not exhibit a precipitous change in oxygen index as the thermal environment of the sample increases. Materials which exhibit glowing combustion following ignition and "flame-out" should be avoided, if possible, or at least treated to eliminate glowing combustion. In cases where wood studding is used to support other materials consideration should be given to a flame retardant treatment for the wood.

Concerning smoke generation, values of D_m as high as 200 in 4 minutes have been proposed as acceptable in some situations. In cases where several materials meet the maximum smoke density criteria the value of time to D_s = 16 should be considered since this value will give an indication of the rate of smoke generation in the early stages of combustion. Materials should be selected which have the lowest value of D_m and the longest time to D_s = 16. Regarding the flash ignition criteria the obvious choice would be a material with the highest possible flash ignition temperature, which might eliminate the material as a secondary source of ignition or, at least, forestall flashover.

Within this context, one would be reluctant to approve the use of most of the materials submitted for testing. The use of glass wool, or a more fire resistant foam insulation would be advisable and Type 2 wall covering would be more acceptable than the Type 1 material. There are, undoubtly, alternative materials available at this time which will be expensive to procure but more cost effective in the long term.

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